Multi-D Simulations of Core Collapse Supernovae

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PRESENT

- VULCAN/2D (Livne, Burrows, et al. 2004, ApJ 609, 277)
  - Explicit, Newtonian radiation hydrodynamics
  - ALE (Arbitrary-Lagrangian-Eulerian) scheme
  - Neutrino transport:
    - Full 2-D Multi-angle, multi-group solver; or
    - Multi-Group Flux-Limited Diffusion (MGFLD)
  - 48 processors - with MGFLD
  - 1000 processors with the multi-angle solver (but needs further development for MPI)
- Recent result: a new possible mechanism of explosion - acoustic power generated in the inner core - Burrows et al. astro-ph/0510687

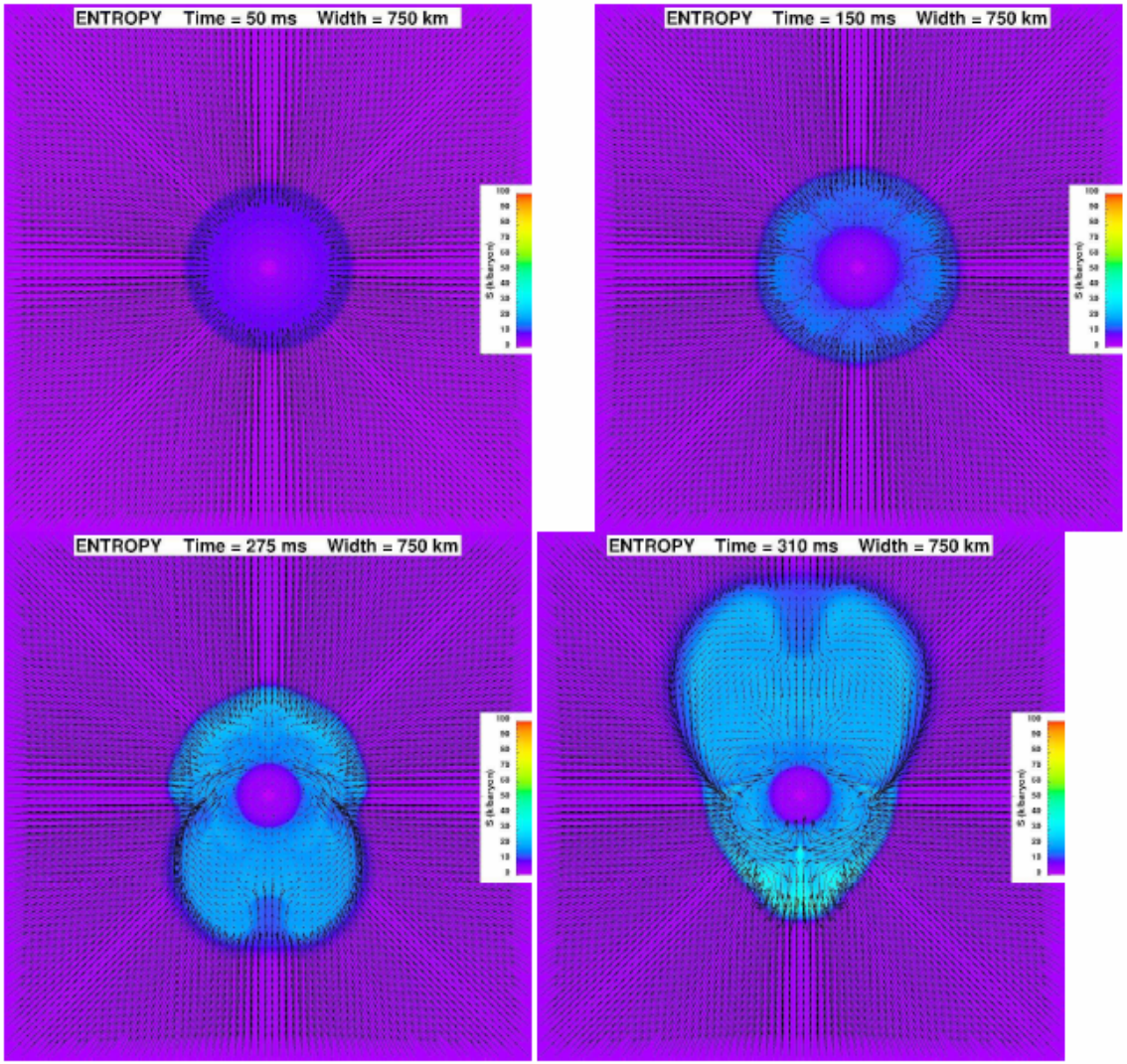

FIG. 1.— Colormap stills of the entropy, taken at 50 (top left), 150 (top right), 275 (bottom left), and 310 ms (bottom right) past core bounce, with velocity vectors overplotted. Here "Width" refers to the diameter through the middle; the radius through the middle is 375 kilometers. Note that on this figure, as well as on Fig. 2, for ease of comparison between panels the same colormap is used. It extends up to 100 units (red), above which it saturates (See text for discussion). These calculations have been done for a full 180° and the axis of symmetry is vertical.

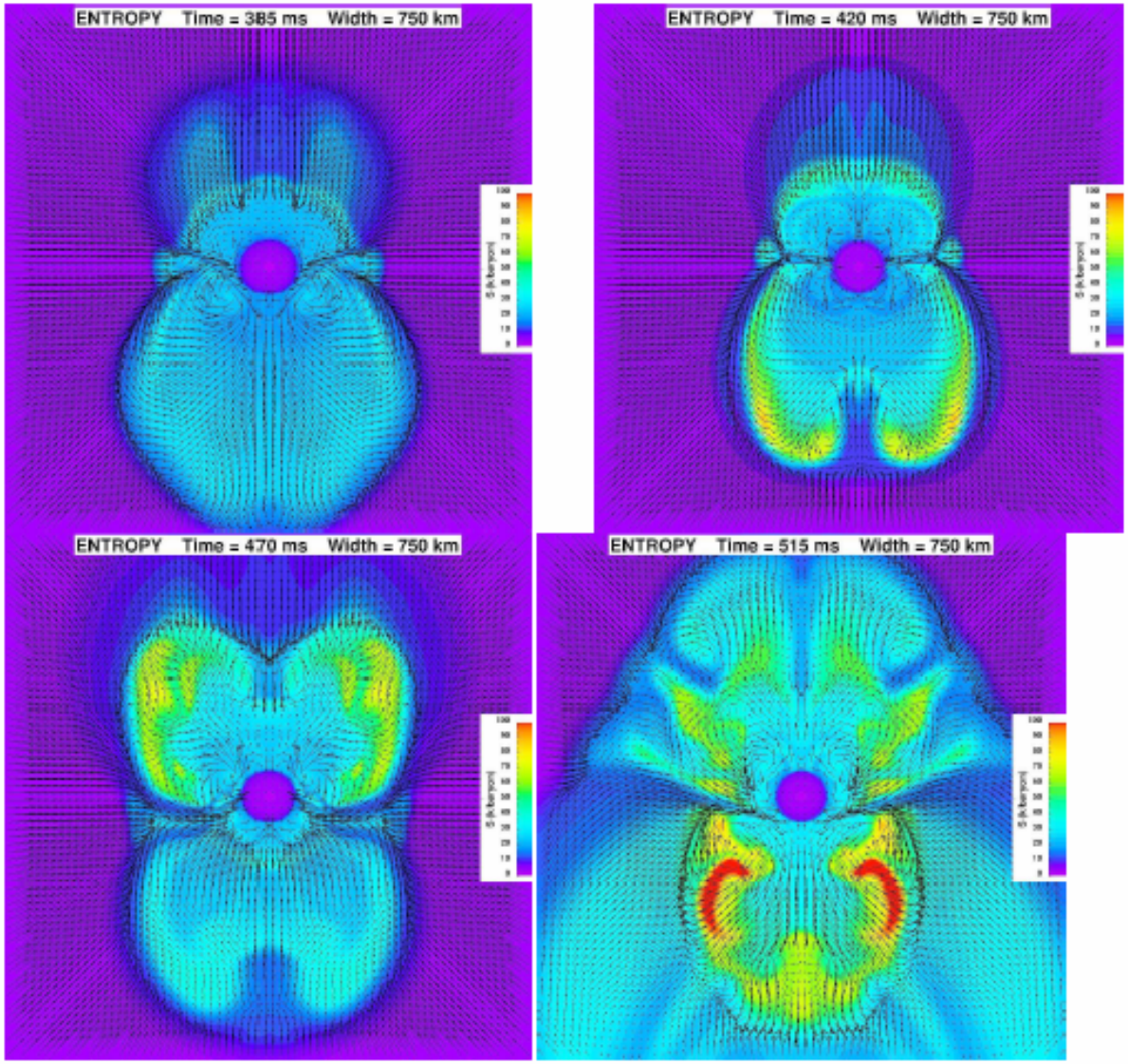

FIG. 2.— Same as Fig. 1, but this time showing the entropy at 385 (top left), 420 (top right), 470 (bottom left), and 515 ms (bottom right) past core bounce (See text for discussion).

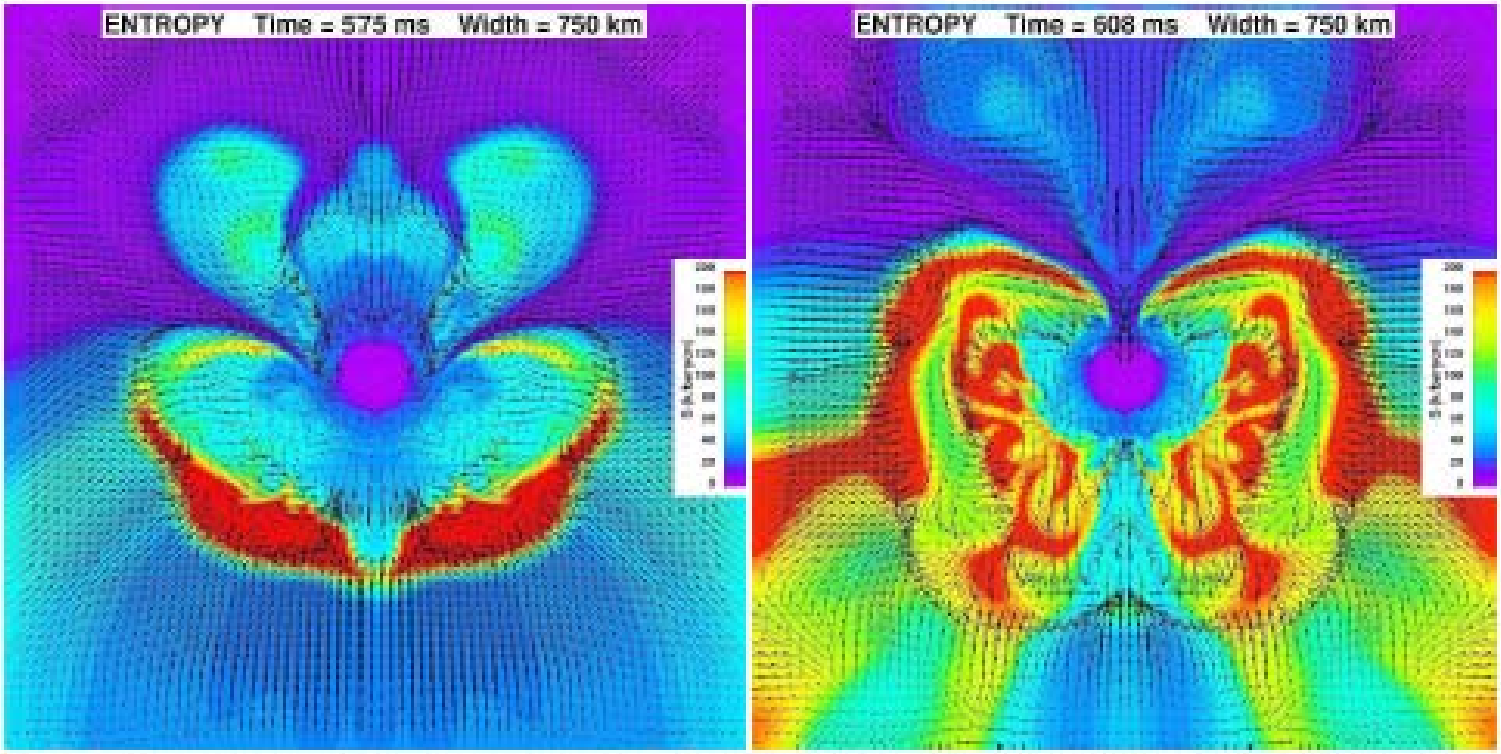

FIG. 3.— Same as Fig. 1, but this time showing the entropy at 575 (left) and 608 ms (right) past core bounce. Note the acoustic waves emanating from the core, most easily seen in the velocity vector field. The color map extends to entropies of 200 (red), and then saturates for entropies beyond 200. The low-entropy accretion streams that are exciting the core g-mode are clearly seen (see text for discussion).

CURRENTLY UNDER DEVELOPMENT: NEW NEUTRINO TRANSPORT SOLVER

- 2-D with rotation (2.5-D), spherical or cylindrical geometry
- Time-dependent, fully implicit
- Multi-group, multi-angle
- Anisotropic scattering
- All velocity terms up to O(v/c) consistently included with the so-called mixed-frame approach - a synergy of Eulerian and Lagrangian (co-moving) frame approaches
- Discontinuous Finite Element solver for the individual angle-dependent Boltzmann (transport) equations
- Suitable preconditioners (ALI) + Krylov subspace methods (currently Ng and GMRES) to solve large linear systems

FUTURE

- New ALE hydro code in 2-D combined with 2.5-D multi-angle neutrino transport (~ 1 year)
- Extension to 3-D (~3 years)
- Adaptive Mesh Refinement (AMR)
- 3-D hydro + 3-D transport: 7-D problem (~ hopefully soon, but do not dare to predict)